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THE EFFECTS OF ROTARY MOTION ON TASTE AND ODOR RATINGS: IMPLICATIONS FOR SPACE TRAVEL

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Astronauts have reported that food eaten in space tastes different or bland. This experiment was designed to investigate the possible role of the motion component of space travel as a contributor to taste and/or odor preference shifts. Two subjects from the Ashton Graybiel Spatial Orientation Laboratory were used to examine the effects of motion in a rotating room on taste and odor ratings. Solutions of NaCl, sucrose, citric acid, and quinine sulfate for taste tests and 10 food odorants for odor tests were rated on both intensity and pleasantness qualities before and after time spent in a rotating room. There was an effect of this motion in one subject whose ratings differed significantly on post-rotation tests. This fact lends support to the idea that motion may be a part of the reported taste changes in space. Keywords: spinning (motion).

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PREFACE

An experiment to assess taste and/or odor preference shifts as a consequence of rotary motion was performed as part of contract no. DAAL03-86-D-0001. It was conducted with the collaboration of the Ashton Graybiel Spatial Orientation Laboratory at Brandeis University in Waltham, MA. The two subjects in this experiment were students at the laboratory. This report presents the results of the experiment and its implications for space travel.

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INTRODUCTION

Astronauts have reported that food eaten in space tastes different or bland. These reports have occurred since the early space missions. In the Russian space program, Cosmonaut Tereskova, in Vostok VI (1963), reported a reduced appetite for sweets and a desire for pungent food tastes. In Soyuz 26, Cosmonaut Gretchko found that canned ham tasted too salty in space, although it tasted fine on Earth. In later missions, one crew reported cravings for foods like apricot juice and honey.[1]

U.S. astronauts of the Mercury, Gemini, and Apollo space programs reported similar perceptual changes,[2] as did Skylab astronauts. The crew of the Skylab 2 mission (1973) reported that food tasted bland; e.g., good tasting bread on Earth was "very much different...and worse tasting" in space. German potato salad, sent up to Skylab and placed in the pantry for use by all three Skylab crews, was eaten entirely by the first crew, who craved the spicy taste.[3] More and varied spices were sent up on Skylab 3 and 4 to improve the taste of the food.[4]

The Command Module Pilot on the Apollo-Soyuz flight (1977), also noticed changes in food tastes and preferred salty foods,[5] while on the Salyut 6 Space Station mission (1977), Gretchko and Romanenko depleted their three month supply of condiments (e.g., horseradish, mustard) in five weeks and had to be resupplied.[6]

In addition to the preceding anecdotal pieces of information, two taste experiments have been performed in space. The first was a taste and smell test on Skylab 4 in 1973[7] to determine if taste thresholds change in zero gravity. Unexpectedly, the inflight results indicated idiosyncratic changes in taste thresholds. One crewman experienced an increase in salt sensitivity, while another experienced an increase in sweet sensitivity. Both of these threshold shifts could be responsible for changes in the perceived taste of foods in flight. Unlike the gustatory tests, the olfactory test showed no change in odor detection.

The second set of taste and odor experiments was performed on Shuttle mission 41G in 1984.[8] These tests involved threshold determinations administered preflight, inflight, landing day, and postflight. No changes in either taste or smell were found for the two individuals who participated in the test. However it was suggested that, since these two crew members did not experience space motion sickness, perhaps the reported changes in taste occur only in individuals who are afflicted by space motion sickness. In fact, in the Skylab 4 mission, one of the two crewmen who experienced a taste threshold shift also experienced space motion sickness on the first day in space.

Space motion sickness can occur in response to exposure to gravity forces of less than or more than 1G. Altering the gravitoinertial force on Earth is accomplished by flying an aircraft in parabolic trajectories.[9] These flight trajectories have been used to help classify subjects as to susceptibility for motion sickness.[10] Research at the Ashton Graybiel Spatial Orientation Laboratory at Brandeis University has focused on the development of adaptation procedures to alleviate the motion sickness experienced in these flights. The adaptation procedures, including a series of head movements, are performed by subjects seated in a revolving room. The revolving room is circular, approximately 20 ft in diameter, and can be rotated at various speeds. The first adaptation session starts at 0.5 rpm and increases each session by 0.5 rpm. Each session lasts about two hours and sessions are performed two or three days per week.

The present experiment was conducted using subjects who participated in these adaptation procedures. Since the previously reported taste problems in space have not been amenable to analysis of taste threshold shifts, the purpose of this experiment was to investigate possible shifts in suprathreshold intensity and preference judgments, which may occur in response to rotary motion.

METHODS

A. Subjects.

Two female graduate students, aged 23 and 25, from the Graybiel Laboratory served as subjects.

B. Materials.

Five concentrations each of reagent grade NaCl, sucrose, citric acid, and quinine sulfate were mixed with distilled, deionized water, along with a water blind (see Table 1). All solutions, except NaCl, were prepared 24-48 hours before each use. Test stimuli of 10 mL each were delivered in 50 mL plastic cups.

Ten food odorants were used: banana, bacon, beef, Romano cheese, clams, coffee, garlic, green pepper, hickory smoke, and peppermint (see Table 2). Each odorant was packaged in a 9 mL glass bottle with a plastic cap. A cotton ball containing several drops of the odorant was placed in a bottle and the bottle opening was covered with gauze. Masking tape was then placed around each bottle to eliminate visual cues to the identity of the odorants. Response sheets for rating the intensity and pleasantness/unpleasantness of samples were provided with each taste and odor stimulus.

A 200 item preference questionnaire was administered, which was a modified version of the Food Preference Survey of the U.S. Army Natick Research and Development Command, January, 1977.

TABLE 1

Concentrations (M) for stimuli used in the taste test

NaCl	Sucrose	Citric Acid	Quinine Sulfate
0.0256	0.01	0.001	0.000022
0.064	0.032	0.0032	0.000066
0.16	0.10	0.010	0.00022
0.40	0.32	0.032	0.00066
1.0	1.0	0.1	0.002

TABLE 2

Food odorants used in the odor test

Code	Odor	Source
1	BANANA	Pentyl Butyrate 2362, lot 691-1d, Eastman, Rochester, N.Y.
2	BACON	Imitation Bacon Flavor f-6230, Givaudan Corp., 321 44th St., New York, N.Y., ESROLKO Div.
3	BEEF	Imitation Beef Flavor 4452, McCormick & Co., Cockeysville, Md., Industrial Div.
4	ROMANO CHEESE	Romano Cheese Flavor imitation, Naarden Inc. 14767, rr 36349, Owens Mills, Md.
5	CLAMS	Baby Clam Extract Flavored Powder 8482, Amano Jitsugyo Co. Ltd., Hiroshima, Japan
6	COFFEE	Natural & Artificial Coffee 2836, Henry H. Ottens Mfg. Co., Philadelphia, Pa.
7	GARLIC	Resoleum Garlic, not specified
8	GREEN PEPPER	Not specified
9	HICKORY SMOKE	Oil soluble hickory smoke, not specified
10	PEPPERMINT	Ethyl Salicylate ex850 2376, Matheson, Coleman, & Bell, Norwood, Ohio

C. Procedure.

Each subject was tested individually. Testing took place before and after the subject participated in the rotary adaptation procedure in the revolving room. Each subject was tested on a total of six days for the taste and odor tests and two days for the food item preference questionnaire, over the course of four weeks. The rpm of the room ranged from 0.5 on test day 1 to 6 rpm for Subject 1 and 6.5 rpm for Subject 2 on the last test day.

Taste test. The order of presentation of the taste compounds was counterbalanced, and all concentrations within a compound were counterbalanced and presented consecutively, except for the first, which was always the mid-range concentration of the series. Including the water samples, there were 24 samples per test. The presentation order was the same for the pretest and posttest administrations, but a new counterbalanced order was used for each test session.

Each subject rinsed her mouth with deionized water prior to tasting each 10 mL sample. Using a sip and spit procedure, each subject tasted the solution in the whole mouth, spit out, and then recorded the intensity and pleasantness/unpleasantness of each sample. A 45 second interstimulus interval was maintained.

Intensity judgments were made using the method of modulus-free magnitude estimation. That is, subjects assigned an arbitrary number to reflect the perceived intensity of the first stimulus. Subsequent samples were judged in relationship to the first, so that if the first sample was assigned a value of 10 and the second sample was perceived to be twice as intense, it would be assigned the value 20; if the second sample was perceived to be one third as intense as the first, it would be assigned the value 3.33, etc. Pleasantness/unpleasantness was rated on the linear graphic scale, consisting of a 204 mm line that was labeled "extremely unpleasant" at one end and "extremely pleasant" at the opposite end. The midpoint was labeled "neither pleasant nor unpleasant". Subjects placed hash marks at the appropriate place on the line to indicate their perceived level of pleasantness or unpleasantness.

Odor test. The order of presentation of the 10 test odorants was counterbalanced. The same order was used for both pre- and postrotation tests and a new order was used in each test session. The subjects uncapped one bottle at a time, held the mouth of the bottle approximately one inch from their nostrils, inhaled the odorant, and replaced the cap. Then each rated the intensity of the odor using magnitude estimation, and the pleasantness/unpleasantness using the linear graphic scale.

Questionnaire. The food preference questionnaire was administered to each subject on two days other than those during which the taste and odor tests were conducted. The questionnaire addressed two questions: How much do you like or dislike this food? and How much would you like to eat this food right now? Responses were made by circling a response alternative for each listed food name, using a 9-pt category scale, where 1 indicated "dislike extremely" and 9 indicated "like extremely". The questionnaire was completed both before and after the subject participated in the rotary adaptation procedure in the revolving room.

RESULTS

A. Taste Tests.

The data from the taste tests were normalized and analyzed by analysis of variance. An analysis of the data collapsed across compounds yielded an expected main effect of intensity for both subjects. For Subject 1, $F(4,92) = 28.31$, $p = <.01$; for subject 2, $F(4,92) = 29.77$, $p =<.01$. The stronger the concentration, the higher the perceived magnitude rating. This effect was also seen for each compound separately.

The data were also analyzed for an effect of time collapsed across days, i.e., a difference in ratings before and after time spent in the revolving room. Although there was no effect for Subject 1 ($F(1,23) = 3.36$) (see Figure 1), there was a significant main effect for Subject 2 ($F(1,23) = 7.43$, $p = <.05$). This subject had higher perceived intensity ratings for the taste solutions after the time spent in motion (see Figure 2). This effect was observed for all four taste compounds.

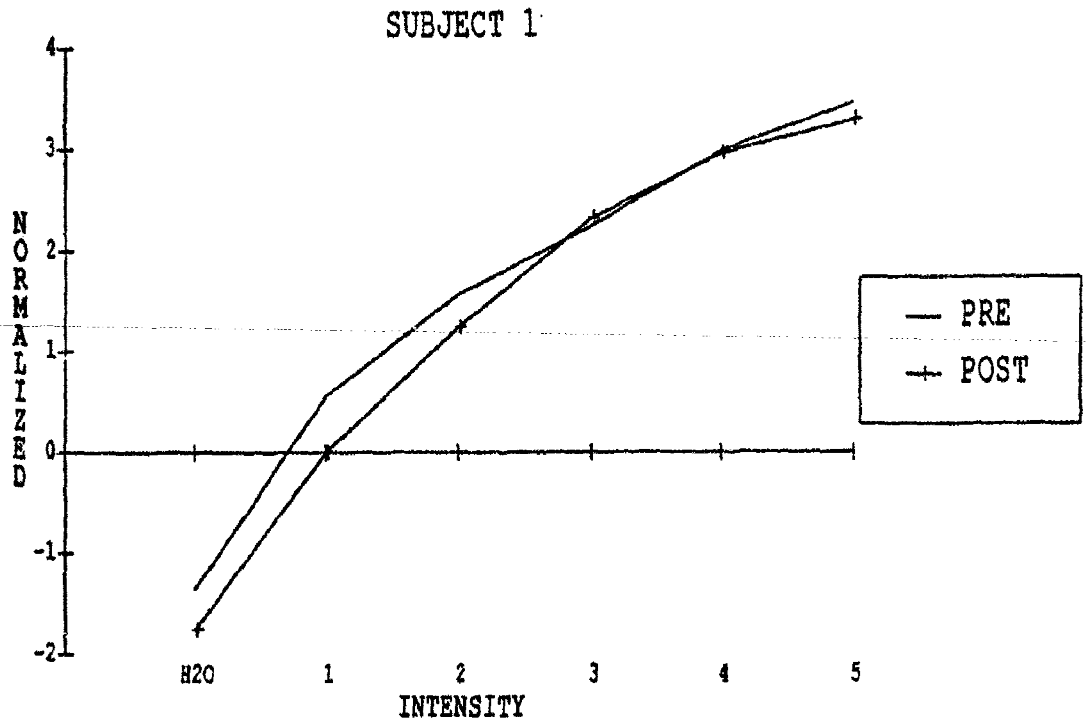

Figure 1. Pre- and postrotation geometric mean magnitude estimates collapsed across compounds for the 5 concentrations of taste solutions - Subject 1.

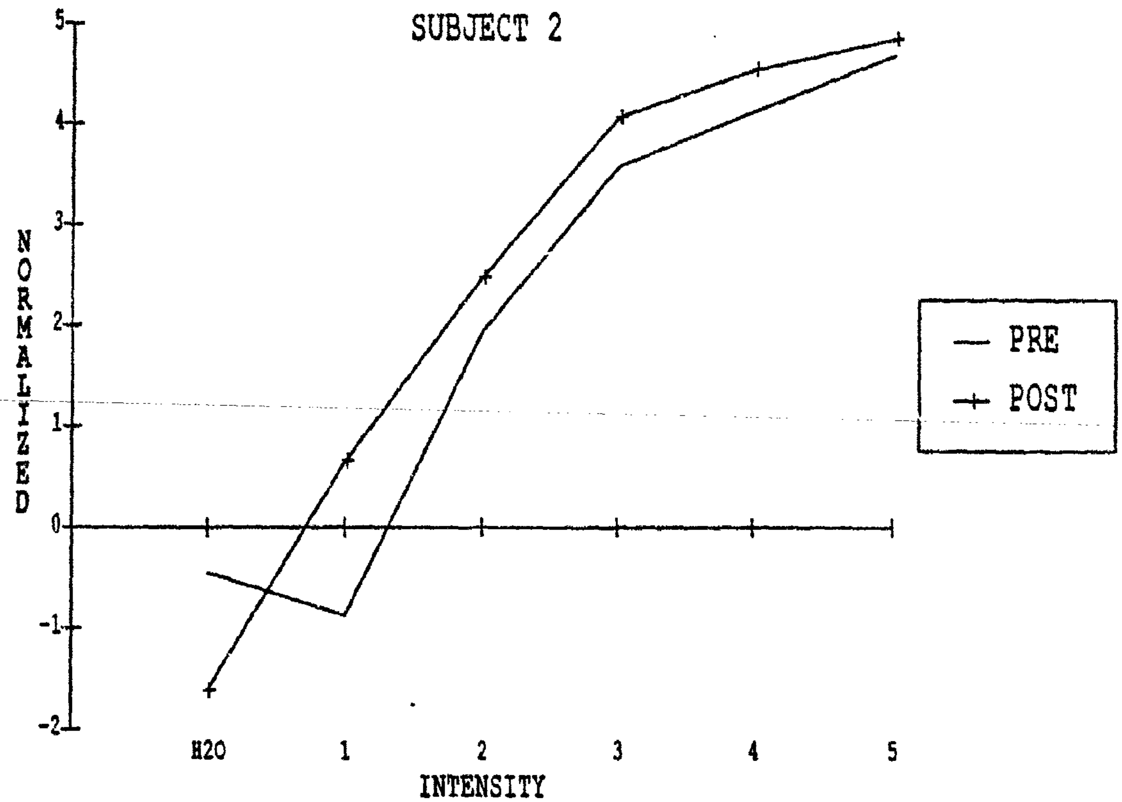

Figure 2. Pre- and postrotation geometric mean magnitude estimates collapsed across compounds for the 5 concentrations of taste solutions - Subject 2.

In order to assess possible changes in the rate of growth of perceived magnitude as a function of solution concentrations, psychophysical power functions of the form $S = kI^n$, where S is the perceived sensory magnitude, I is the solution concentration, n is the exponent of the power function, and k is a constant of proportionality, were calculated for each subject, compound, session, and time of test. Figures 3 to 10 are plots of these data showing both the exponents (slope of the function in full log coordinates) and constants of proportionality (intercept of the function in full log coordinates). Table 3 shows the median exponents across days for each compound, time of test and subject. From these data it is clear that Subject 2 had a much greater responsitivity to changes in solution concentration than Subject 1, as evidenced by Subject 2's much higher exponents. However, matched t tests performed on the exponents showed no effect of time of test for any compound in either subject.

Examination of the pleasantness/unpleasantness ratings showed that there was no significant change in ratings between pre- and postrotation time. However, the changes that did occur were shifts to a less pleasant rating on the postrotation tests. For Subject 1 the shift to a less pleasant rating was seen in the four highest concentrations of all the compounds, with more changes occurring for citric acid and quinine

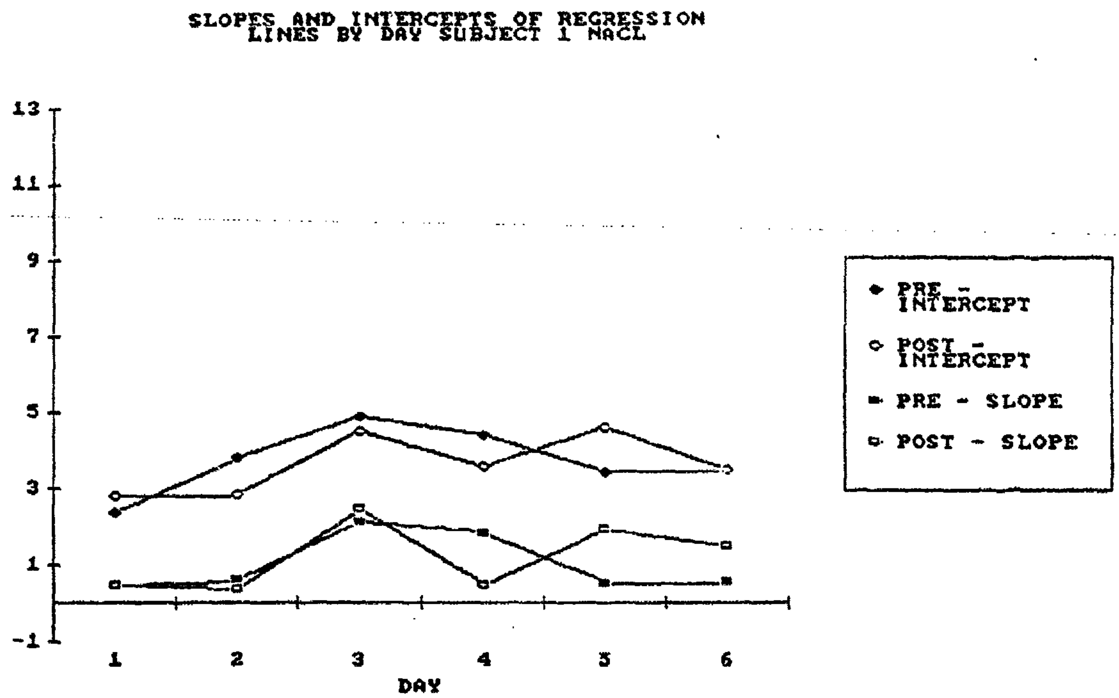

Figure 3. Slopes and intercepts of regression lines by day - Subject 1, NaCl.

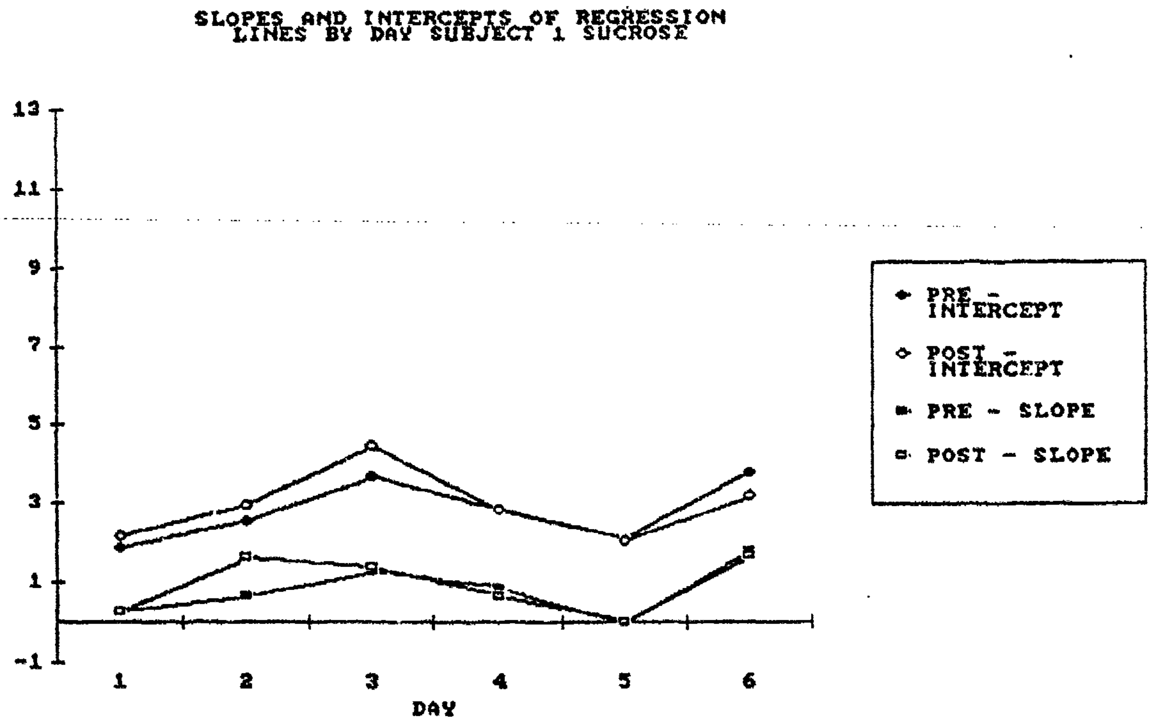

Figure 4. Slopes and intercepts of regression lines by day - Subject 1, sucrose.

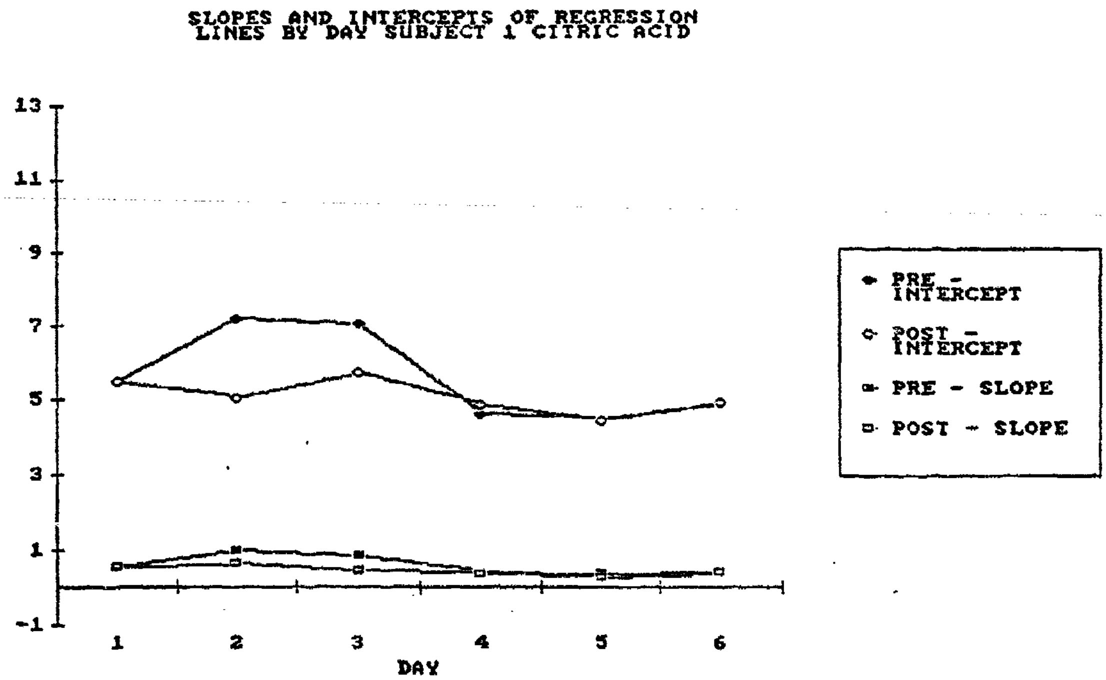

Figure 5. Slopes and intercepts of regression lines by day - Subject 1, citric acid.

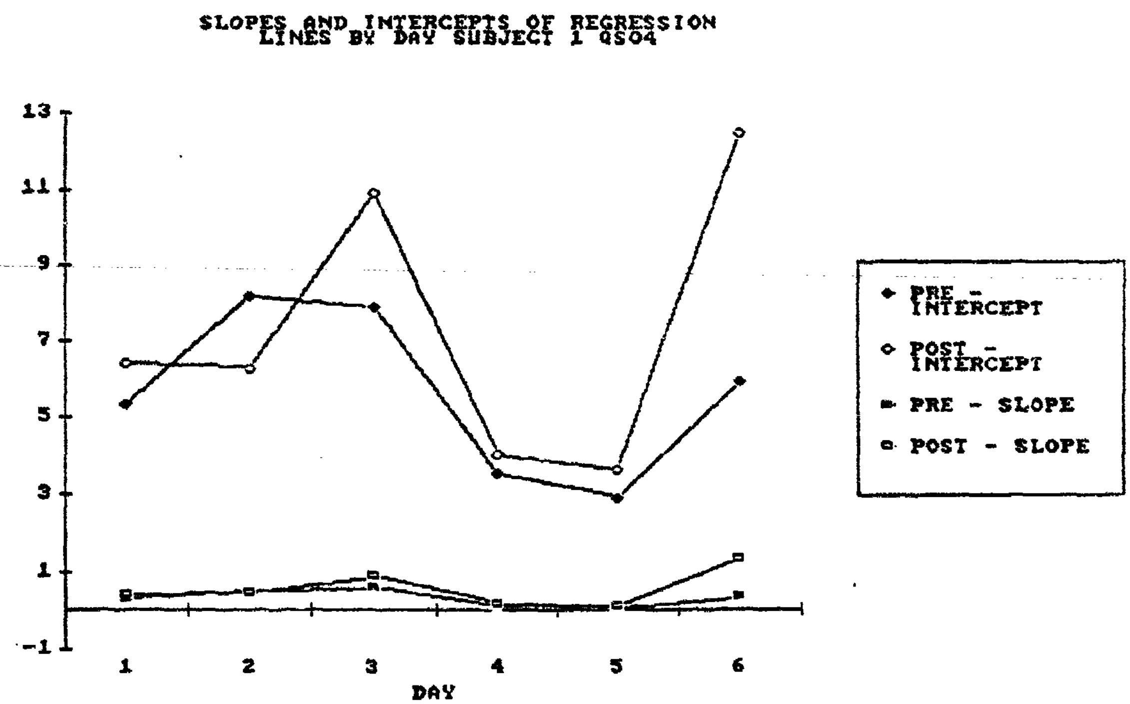

Figure 6. Slopes and intercepts of regression lines by day - Subject 1, quinine sulfate.

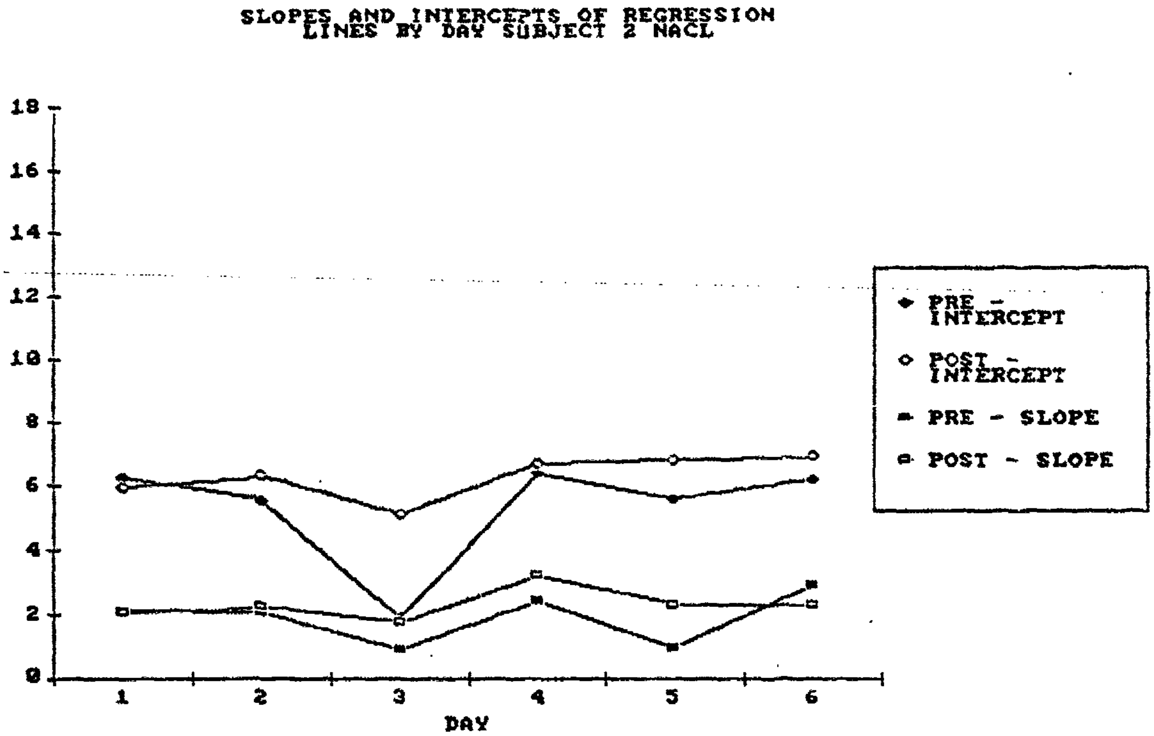

Figure 7. Slopes and intercepts of regression lines by day - Subject 2, NaCl.

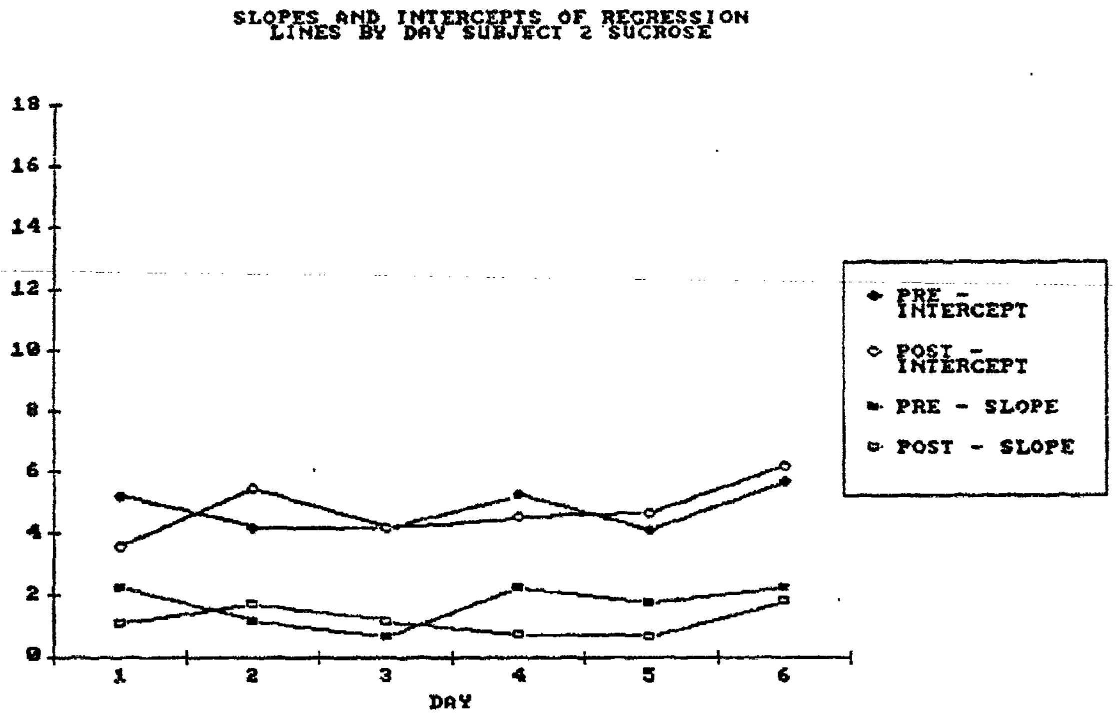

Figure 8. Slopes and intercepts of regression lines by day - Subject 2, sucrose.

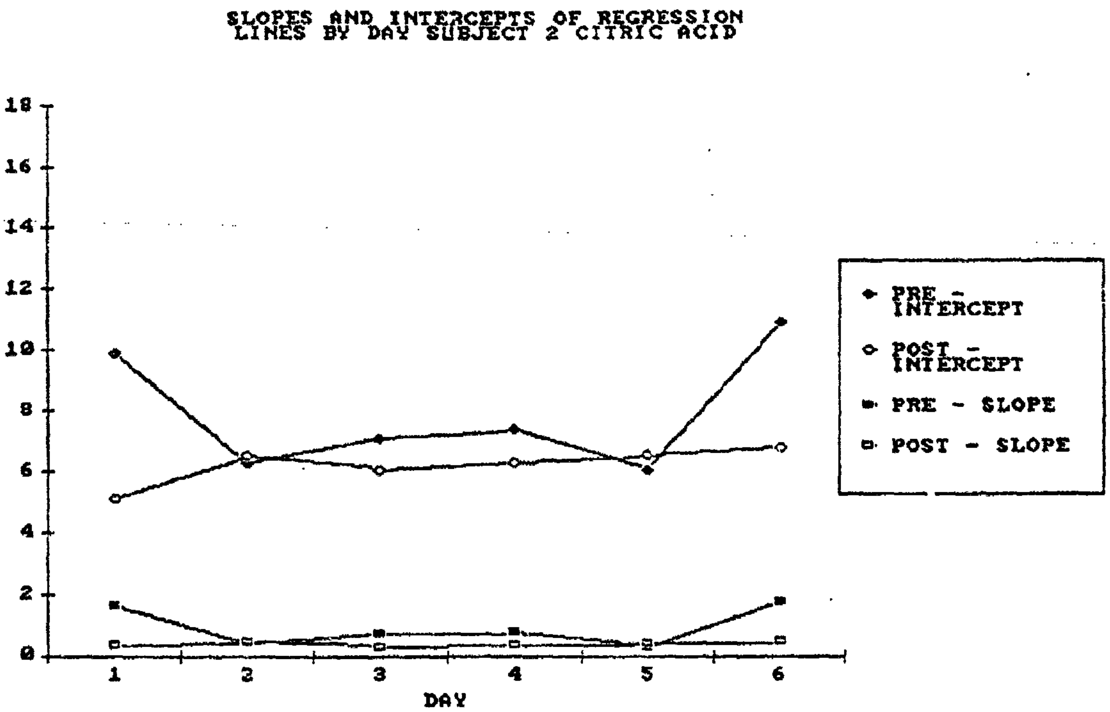

Figure 9. Slopes and intercepts of regression lines by day - Subject 2, citric acid.

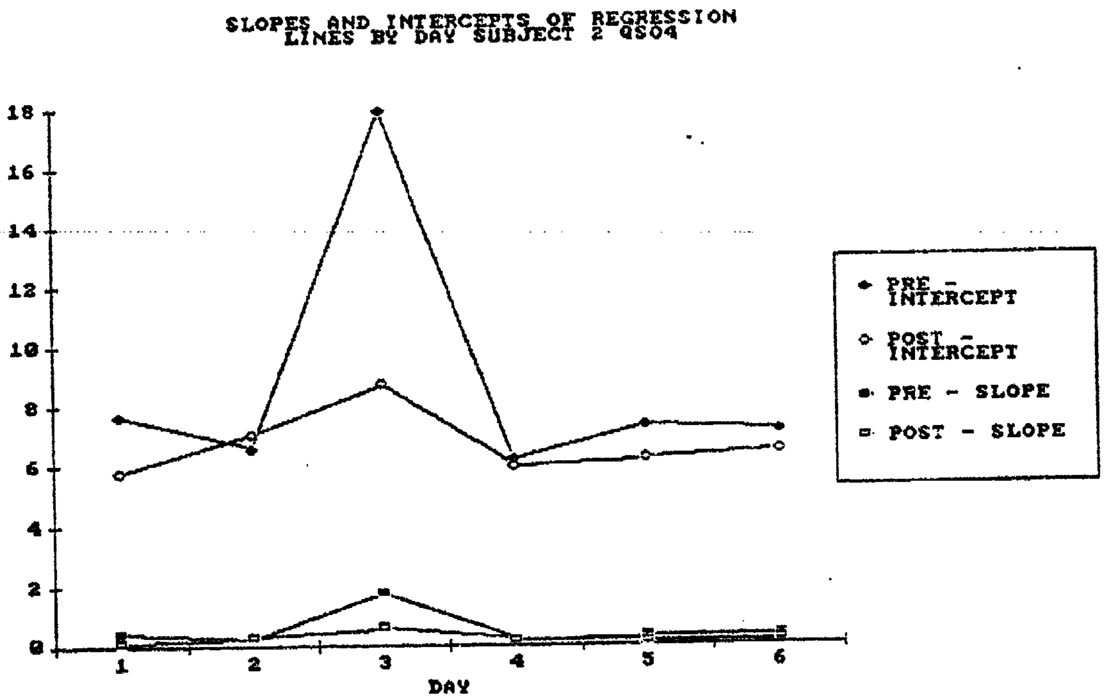

Figure 10. Slopes and intercepts of regression lines by day - Subject 2, quinine sulfate.

TABLE 3

Median pre- and postrotation exponents of the psychophysical taste functions determined from the magnitude estimation data for each subject and compound.

	Subject 1		Subject 2	
	Pre	Post	Pre	Post
NaCl	0.56	0.97	2.09	2.25
Sucrose	0.77	1.00	1.98	1.10
Citric Acid	0.49	0.42	0.74	0.40
QSO_4	0.33	0.43	0.28	0.16

solutions than for salt and sucrose solutions. For Subject 2, most of the shifts to a less pleasant rating occurred in the citric acid series.

B. Odor tests.

There were no significant differences in the ratings (collapsed across days) for either odor intensity or odor pleasantness as a function of the rotation in the room (see Figures 11 and 12).

C. Motion sickness susceptibility.

Each subject also filled out a checklist for motion sickness susceptibility as soon as she finished the adaptation procedure. This checklist had each subject rate such feelings as nausea, pallor, cold sweat, warm/flush, increased saliva, drowsiness, dizziness, headache, and anxiety. They were to check if they experienced "none", "minimal", "moderate", or "major" amounts of these symptoms, except for the warm/flush category, which required a simple yes or no response. Subject 1 on day 4 rated the pleasantness of the cheese odor extremely unpleasant on the prerotation test; on the postrotation test, she rated it extremely pleasant. Also, on the same day, she rated the pleasantness of mint extremely pleasant in the prerotation test and extremely unpleasant on the postrotation test. She also indicated that she felt warm/flushed, had minimal drowsiness and minimal nausea. This was the only report of nausea in either subject on any test day. Subject 1 also felt slightly flushed on 5 of 6 test days. Subject 2 reported none of these symptoms on any test day.

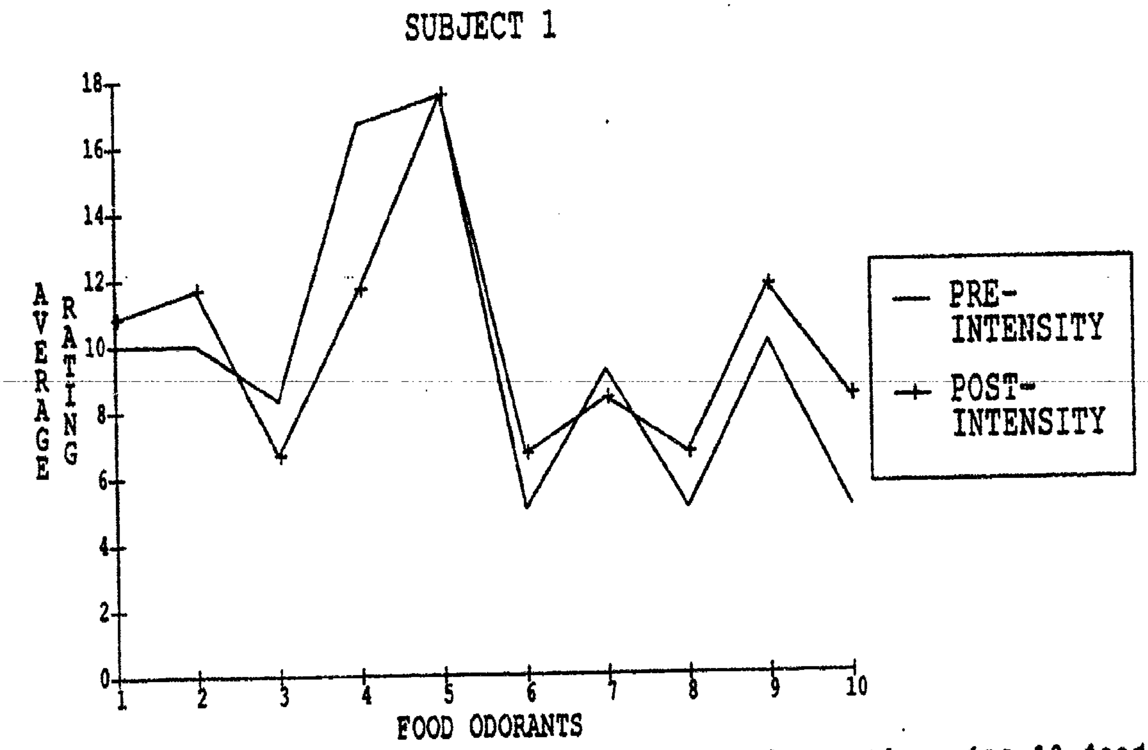

Figure 11. Average pre- and postrotation intensity ratings for 10 food odorants Subject 1.

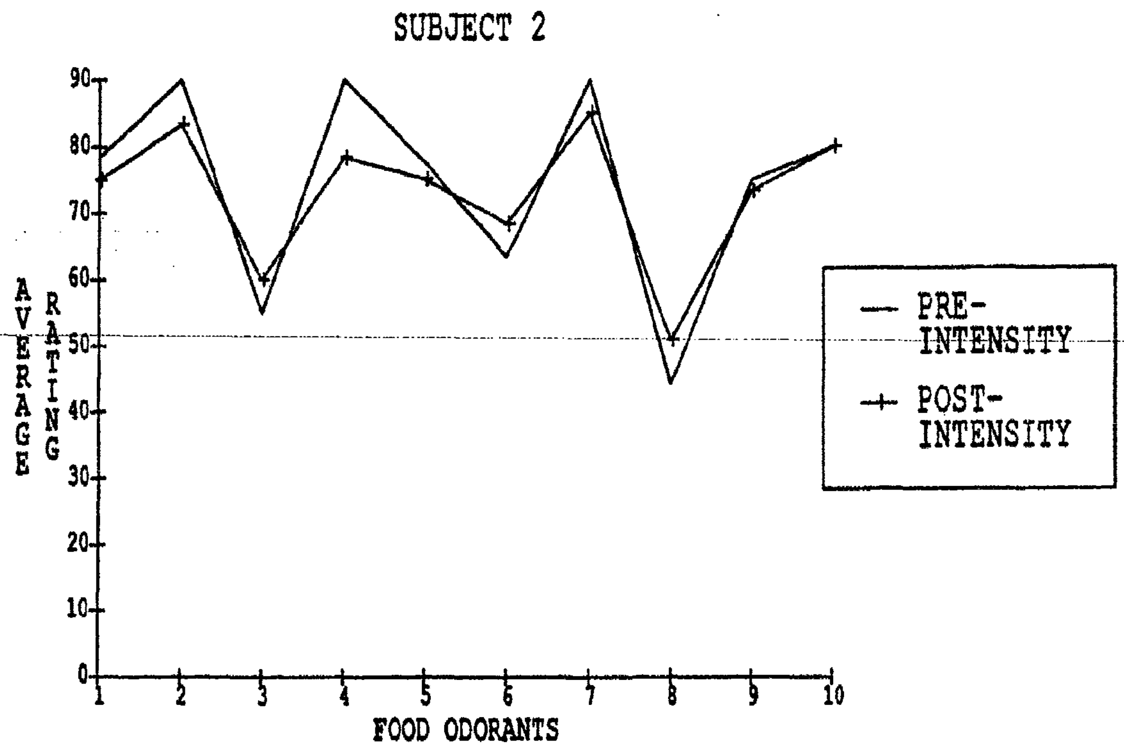

Figure 12. Average pre- and postrotation intensity ratings for 10 food odorants subject 2.

D. Preference questionnaire.

The 200 items on the preference questionnaire were grouped into 18 categories (see Table 4). There were no significant differences in the ratings before or after time spent in the revolving room for either the question concerning like/dislike of the food or desire to eat it now. Overall, the postrotation ratings were lower (more disliked) than prerotation ratings for fruits, snacks, vegetables, and potatoes. There were no differences in soups, seafood, meats, breads, milk products, salads, and desserts. Sandwiches, eggs, cereals, cold beverages, hot and cold, carbonated beverages were rated higher (more liked) in postrotation ratings. The tests were all conducted in the afternoon, after the subjects had eaten lunch.

DISCUSSION AND CONCLUSIONS

There was an expected main effect of concentration on perceived taste intensity; the stronger the concentration, the higher the intensity rating.

For one of the subjects tested there was also an effect of time. This subject had significantly higher ratings of perceived taste intensity for the solutions following the rotary motion adaptation procedure. This finding indicates that there may be a motion component in the reported taste differences in space. Neither of the subjects in this experiment experienced frank motion sickness, but one did have taste perceptions that

TABLE 4

Eighteen groupings for the 200 items in the preference questionnaire.

Groups	Number of items
Soups	8
Cold beverages	9
Hot beverages	4
Carbonated beverages	3
Milk products	10
Breads	2
Cereals	5
Eggs	3
Meats	35
Fish & Seafood	6
Sandwiches	14
Vegetables	25
Salads	12
Fruits	12
Desserts	28
Snacks	5
Potatoes & Potato Substitutes	16
Nonfoods	3
	200

differed in the pre- and postrotation testing. The data on astronauts who experienced motion sickness are well documented. However, the reported taste differences are rather general and anecdotal. Except for certain instances, the reports are not connected specifically to an astronaut that experienced space motion sickness. Perhaps the motion involved in space travel and weightlessness is a component in these taste changes. The motion may contribute to a predisposition in individuals to experience these changes, without necessarily experiencing frank motion sickness. However, the mechanism of these changes is not yet understood.

It is important that more testing be done to ascertain the extent to which motion is involved in these reported taste changes. Ideally, testing in the weightless conditions of space flight would be the most beneficial way. The next step would be to test gustatory and/or olfactory changes in parabolic flight, the nearest condition to weightlessness.

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